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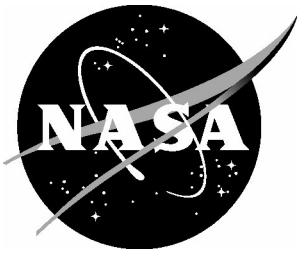

Integrated Mode Choice, Small Aircraft Demand, and Airport Operations Model User's Guide

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February 2004

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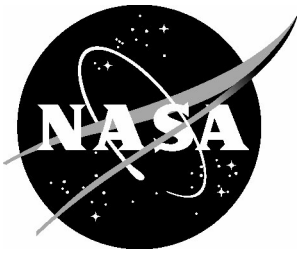

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Abstract

A mode choice model that generates on-demand air travel forecasts at a set of GA airports based on changes in economic characteristics, vehicle performance characteristics such as speed and cost, and demographic trends has been integrated with a model to generate itinerate aircraft operations by airplane category at a set of 3227 airports. Numerous intermediate outputs can be generated, such as the number of additional trips diverted from automobiles and schedule air by the improved performance and cost of on-demand air vehicles. The total number of transported passenger miles that are diverted is also available. From these results the number of new aircraft to service the increased demand can be calculated. Output from the models discussed is in the format to generate the origin and destination traffic flow between the 3227 airports based on solutions to a gravity model.

Introduction

The methodology to analyze the demand and operations for General Aviation (GA) and Small Aircraft Transportation System (SATS) that is reported in references 1-3 has been integrated into a single EXCEL workbook. The Integrated Mode Choice (Ref. 1), Small Aircraft Demand (Ref. 2), and Airport Operations (Ref. 3) Models are a linked set of spreadsheets so that a single change in any input variable is propagated through the various models to generate the demand, number of operations, and the input to the SATS Flight Demand Model (Ref. 3). The SATS Flight Demand Model can then be used to generate a typical daily flight schedule of itinerate flights for the GA fleet. Inputs to the SATS Flight Demand Model are the number of operations by airplane category (ex. single engine piston, multi-engine piston and turboprop, and business jets) at each of the 3227 airports.

A major impetus behind the integration of the methodology into a single set of spreadsheets is that the two models to generate aircraft demand and to generate airport operations developed by Logistics Management Institute (refs 2 and 3) used different criteria to select the subset of GA airports with the qualities for SATS operations. The aircraft demand model (Ref. 2) included the 2865 GA airports in the continental US with 10 or more itinerate operations in 1998. The operations and trip generation models are based on a larger set of 3227 airports included in the NPIAS (National Plan of Integrated Airport Systems). The 2865 airports were not a simple subset of the larger set and a fairly large disconnect had to be resolved. In fact, 637 airports in the 2865 set are not included in the larger set. Thus data from 3864 airports are needed to use both models to develop the aircraft demand, aircraft basing, operations, and trip projections. Data for the airports not included in the 2865 airport set was extracted from the National Transportation Atlas Databases (NTAD) (Ref. 4) which contains data for approximately 19,800 landing

facilities. The NTAD includes airport location, physical description, points of interest, etc, as well as the numbers of based aircraft by category and the airport operations by type of service for both local and itinerate flights. Terminal Area Forecast (TAF)(Ref.5) data was used to project based aircraft and operations for future years for most of the non-common airports. A small number of airports were not the TAF database. Also, the majority of 637 non-common airports are small airports that project no growth in the TAF. Many have been losing aircraft in the last few years, and thus, aren't optimistic about gaining either aircraft or operations.

Historical airport and aircraft operational data and county demographic data are used to determine the present and to project the future numbers of aircraft, aircraft basing, and aircraft operations. New aircraft or concepts of aircraft operations that disrupt the historical trends may be introduced. The user can then simply bypass the program calculations that determine the numbers of aircraft and operations from trip demand and insert the operations data for the new concept to replace the results of calculations based on historical data. The linked calculations are the reference, or business as usual response to additional trip demand. The operational projections associated with the new aircraft or concept of operations from the mode choice model that resulted in the increase demand can be inserted directly thus bypassing the calculations that would project today's usage into the future. For example, low cost jet air taxi operations are expected to have about 4 times the number of annual operations and flight hours per aircraft compared to business jets in corporate service, thus, the business jet utilization numbers from the General Aviation and Air Taxi Activity (GAATA) Survey (Ref. 6) need to be directly adjusted to reflect the new type of service.

The aircraft basing numbers by airplane category and the annual GA itinerate operation data were combined to produce projected annual itinerate operations by airplane category for each airport. These data can then be used to produce the GA origination/destination (O&D) traffic flow (not part of the EXCEL spreadsheet model) based on solutions to a gravity model (Ref. 3) The O&D traffic "schedule" is developed by a Monte Carlo simulation that assumes the distribution of originating airports is based on annual itinerate operations by airplane category, the distribution of destinations from an originating airport is based on the annual traffic flow from the gravity model, and departure time of day is based on analysis of Enhanced Traffic Management System (ETMS) data. Also, since itinerate flight demand for GA aircraft varies greatly with time of year and the day of the week, the average daily total of flights is adjusted to simulate a high traffic day.

Details of the linking of the models and a worksheet-by-worksheet explanation of the inputs and calculations are presented in the report. In actuality, since the models are linked in EXCEL spreadsheet, it is very simple to change almost any aspect of the models to capture additional or new scenarios, such as personal air vehicles or competition from other modes of transportation in addition to automobiles and scheduled air. Future details of the models are available in references 1 to 3.

Model Linkage

The linkage of the core models is illustrated in Figure 1. The mode choice model is documented in detail in references 1 and 2. The model is a macroeconomic model that projects at a National level the mode choice between automobile, scheduled air, and on-demand air based on the monetary cost of the trip and the value of the traveler's time for a given year from 2000 to 2025. Output is the annual demand measured in the number of person trips and the number of transported passenger miles for the 3 modes of transportation. The mode choice model is broken into sub-models for business travel and for pleasure and personal business travel so as to capture different price sensitivities.

The total number of transported passenger miles by on-demand aircraft is input to the aircraft basing and operations model for the 2865 SATS airports to forecast GA demand at the airport level (Ref. 2). The automatic linked path through the analysis projects future aircraft mixes and operations in proportion to today's fleet and trends with growth determined from either demographic or NPIAS data. However the intent of NASA technology is to break with the past with new and better systems that fulfill needs not met by existing systems. For these disruptive systems, the user simply breaks the automatic links by directly inputting data. For example, in addition to payload, block speed, and range a new GA aircraft has fixed cost per trip and cash cost per mile based on the aircraft price, hanger fees, insurance, pilot salaries, etc. and the annual flight rate. Additional person trips and transported passenger miles will be diverted to GA as a result of faster and/or lower priced service. Dividing the additional trips by the airplane utilization and passengers per flight assumptions results in the number of aircraft needed to meet the increased demand. This number of aircraft can be added directly to the based aircraft table for that type of aircraft. The basing of the aircraft in that category is then a function of the demographic data. Note that the number of additional aircraft projected should not be interpreted as the total market for the new aircraft. Since the airplane was faster and/ cheaper that existing products offered, it should capture some or much of the existing market in addition to the market diverted for other transportation modes. This replacement of retired aircraft and normal growth is already included in the baseline numbers, so the total market for any new aircraft is higher than just the additional trips diverted from other travel modes. Whether the new aircraft is a replacement for an existing aircraft or part of the diverted market, the numbers of itinerate operations by airplane category at each of the 3227 airports are captured in the projections.

The number of total itinerate operation and based aircraft data for each airport (by year) is then combined with GAATA data for aircraft flight rate and operations distribution for each aircraft category and each FAA region to project operations by aircraft category.. The GAATA data is historical data, so when disruptive numbers of operations for a particular aircraft are added, the GAATA data table for that aircraft category's annual itinerate operations must be modified to reflect the incremental operations. This modification should be consistent with number of operations added to the airport GA itinerate ops spreadsheet. Output from this model serves as input to the SATS model which generates origination and destination traffic flow based on solutions of the gravity

model from which it then generates flights using a Monte Carlo simulation and a departure time of day profile. Details of the SATS flight generation are in reference 3.

The airport reconciliation methodology is illustrated in Figure 2. The two models from references 2 and 3 were checked for common airports and a table of airports not common in the two models was generated. The NTAD of landing facilities was interrogated for the current number of itinerate GA operations and the number of single engine piston, multi-engine piston and turboprop, and jet aircraft bases at those airports. The Terminal Area Forecast (TAF) System was then interrogated for forecasts of future operations and aircraft basing at the non-common airports. In what is possibly a reflection of recent history of general aviation, only 20 or so of these airports in the non-common set forecasts growth. Fortunately (from a methods development point-of-view) the majority of the non-common airports have few operations and based aircraft so the overall effect on O&D projections is small, especially for low cot jet air taxis. The non-common airport and data are copied and then added to the aircraft demand model tables to form a complete set of data from which the airport and operations demand model can generate the inputs to the SATS Model. The EXCEL data link with the airport reconciliation worksheets is severed since the process does not require updating without new FAA data and maintaining the link would add greatly to the calculation time.

Note that the airport location identifiers (LOCID) are a significant problem. Approximately 800 LOCID's have been changed since 1996, so when an airport appears to disappear from a data set, it probably has a new LOCID. The web site, www.airnav.com/airports/ , contains updated databases of location identifier changes.

Inputs, Outputs, and Methods

Following is a worksheet-by-worksheet description of the inputs, outputs, and calculations starting with the mode choice model which calculates the potential number of on-demand air trips and resulting in an airport-by-airport forecast of operations by each aircraft category. For consistency in the year of the projection, the year should be input in cell G2 on the ops&AC worksheet, otherwise the year input only changes the year on the sheet for which the input is made. All dollars numbers are in year 2000 dollars. The airport reconciliation worksheets are given for reference only and are not active in the projections since there is no need for them to be active and being active would only slow the calculations. Worksheet apt1_1x is the airport data extracted from the NTAD for the 19,800+ landing sites. Worksheet apt1 lists the 5835 landing sites in the US; including Alaska, Hawaii, and US territories; that have more than 10 itinerate operations per year. Worksheet Extra_apts lists the operations and based aircraft data extracted from the NTAD for the non-common airports. The airport reconciliation worksheets are sufficiently explained in the Model Linkage section and thus are not included again in this section.

Pleasure&PB Worksheet

This worksheet calculates the cost of pleasure and personal business trips based on out-of-pocket costs and value of time for automobiles (PA), scheduled commercial air (PSA), and on-demand air (POD). Mode choice is determined by assuming that the traveler will choose the lowest cost mode. How a traveler perceives value of time is highly variable for personal travel and can be adjusted by an input coefficient. Development of the trip cost equations are detailed in reference 2 and enhancements to the mode choice equations are detailed in reference 1.

The principal and named variables are:

- Block speed of the trip (mph)
- Fixed cost ($) which includes cost such as airport parking, taxis, rental cars, etc. that are shared by all members of the travel party
- Fixed time (hr) includes travel to and from airports, rental car drop off, parking to ticket counter, counter to boarding, baggage pick-up, etc.
- Fare fixed cost ($) is fixed cost portion of a scheduled air coach ticket from historical data of ticket cost as a function of travel distance or the fixed cost of ownership of an on-demand aircraft divided by the annual number of trips (half the number of annual flights) On-demand air Fare fixed costs are shared by members of the travel party.
- Fare per mile ($) is the cash cost per statute mile. Note that for automobile travel cost per mile follows the IRS guidelines that are representative of average usage and is not broken into fixed and variable costs. Fare per mile costs for automobile or on-demand air are shared by members of the travel party.
- Per diem cost ($) is the cost of food and lodging per traveler per day
- Coefficient on line-haul a perceived value of travel time multiplier. Department of Transportation (DOT) studies show this to be low (.5) for personal automobile travel
- Coefficient on access/egress is a value of time multiplier for access and egress the transportation system which is the Fixed time number from above
- Range (statute miles) is the distance for on-demand air beyond which a fuel stop(s) is necessary. Each fuel stop is assumed to add an additional hour to the block time.

Other inputs which are variable:

- POD number in Travel Party is the number of persons in the travel party. Default value is the average number of persons in a household for the income bracket from U.S. Census Bureau data (Ref. 7)
- Phourly wage ($) is a table of the mean annual household incomes (Ref. 7) for the income brackets divided by the number of wage earners per household and 2000 hours per year. See reference 1 for a detailed explanation.

The total trip cost equal to the sum of total cash cost plus value of time cost for each mode of transportation, household income bracket, and trip distance is calculated. The lowest trip cost is deemed the mode choice and is attributed the per capita pleasure and

personal business trips for that income bracket and distance. Per capita trips are calculated form the 1995 American Travel Survey (Refs. 2 and 8).

Personal Totals Worksheet

This is an output worksheet that calculates the numbers of personal trips at each distance, total number of trips, and transported passenger miles for each transportation mode. The per capita trip data determined in the Pleasure&PB worksheet is linked to the population data by income level in columns AM to BL. The population table is constructed from U.S. Census Bureau population projections and recent trends within the total population with respect to movement between income brackets. Income projections are in year 2000 dollars. The worksheet for these population numbers is provided as the Scaled U.S. data worksheet. The trip data are summed in the upper table for all three transportation modes and has the totals and distribution of personal travel projected for the U.S.

Business Worksheet

This worksheet is similar to the Pleasure&PB worksheet but the values are for business travel. The mode choices remain automobile (BA), scheduled commercial air (BSA), and on-demand air (DOD). Since inputs are similar to personal travel, only the differences are discussed.

- Fixed time (hr) for business travel is the same as for personal travel except business travel is much more sensitive to the frequency of flight. Thus, it is appropriate to include a time allowance for the time between when business is concluded and he next available flight. Default value in the Business worksheet includes an hour allowance for this situation. Family and personal travel is not as sensitive to frequency of flight and thus has no similar allowance.
- Fare fixed cost and Fare per mile are based on historical business class fares in year 2000 dollars. Recently fares have been highly variable and the spread between business and coach tickets has been decreasing. If the user feels these fare changes are long-term trends, these two inputs may be revised to capture the trend.
- Coefficients on line-haul and coefficients on access/egress for the different modes are usually equal because the business traveler perceives the value of time to be he same regardless of the travel mode.
- Bhourly wage is a table of the mean individual incomes for the income brackets from reference 7 divided by 2000 hours per year. Note that individual income tables are used for the business traveler's value of time and household income tables for pleasure and personal business travel value of time.

Total trip cost is again calculated by the sum of the total cash cost plus the value of time for each income bracket and trip distance. Lowest trip cost among the three modes is chosen as the mode choice and is attributed the per capita business trips for the income bracket and trip distance.

Business Totals Worksheet

This is an output worksheet with the same calculations as the Personal Totals except the population and income data is for individual wage earners than household income. Output is the number of business trips at each trip distance, total number of business trips, and transported passenger miles.

SEB_airport_share

MEB_airport_share

jet_airport_share

GAIT_airport_share

These are four data worksheets of matrices consisting of 2865 rows, each corresponding to an airport, and columns representing the years from 2000 to 2025. Each entry in the matrix represents the share of the total that each airport has or is calculated to have for single engine based aircraft, multi-engine based aircraft, and jet engine based aircraft, and total GA itinerate operations. These data are produced by a 3-year time series approach using regression models for economic and demographic data and projections from the County Projections to 2025 data from reference 9. The process is reviewed in detail in reference 2. In the current form of the model these 4 worksheets are simply data sheets representing each airports share or projected future share of each based aircraft category and GA operations for the 2865 airports. Note that as previously discussed, this information was extracted from the FAA TAF for any airport data required beyond the 2865 airports.

Based single engine aircraft Worksheet

Based multi-engine aircraft Worksheet

Based jets Worksheet

GAIT ops Worksheet

These four worksheets use exactly the same methodology, thus it is expedient to discuss them simultaneously. The four worksheets distribute the basing of single engine, multi-engine, and jet aircraft and itinerate GA operations among the 2865 airports using the airport's share fraction from the share worksheets. For all four of the worksheets, the sum of the transported passenger miles from the Personal Totals and the Business Totals worksheets is the input. Coefficients for the current and future relationships of the total number of single engine, multi-engine, and jet aircraft and itinerate operations to the total number of transported passenger miles are derived from FAA TAF and General Aviation

and Air Taxi Activity (GAATA) data. The basic assumption for the worksheets is that any new aircraft would replace current GA aircraft as they are retired and that the fleet and operations will grow following current trends and demographic projections and in direct portion to increased transported passenger miles. In other words, the future fleet and operations are distributed among airplane categories along current trends. This forecasted distribution of GA aircraft and itinerate operations serves as a baseline against which incremental changes can be measured. Any increases in the numbers of aircraft or operations that results from disruptive technologies are added to the baseline numbers on line 2867 of these worksheets. The total number of aircraft by category and the total number of itinerate operations are distributed to the 2865 airports in the proportions in the airport share worksheets. Data for the airports not in the 2865 set are from the NTAD and TAF are in the rows just below the numbers derived for the 2865 airports.

ops&AC Worksheet

This worksheet reads data for each airport from the GAIT and based aircraft worksheets for the year specified in cell G2.

UTILIZE worksheet

This worksheet is a data table from GAATA data for the number of itinerate flights by aircraft category per year in 1998 at the FAA regional level. The default forecast is to assume that the aircraft flight rate remains stable. However, if the fare costs for on demand air travel in the mode choice model are based on increased flight rates for a particular airplane type (such as, air taxi operations for low cost jets) the increased utilization should be factored into the table in proportion to the increased number of flights for that airplane.

ops_distribution Worksheet

This worksheet is another data table and is the percentage of landings in an FAA region by each airplane category. The table is from GAATA data and the percentage arrivals by aircraft category for the region is derived from the total itinerant landings in 1998 by category and region. Any changes in the aircraft utilization introduced in UTILIZE can be carried over to this sheet. Reference 3 has a number of other tables, such as the number of aircraft by category and region, that aid in the redistribution to reflect the economic assumptions of the mode choice model. Cautionary note: The ops distribution table is based on regional flight arrival data and thus reflects the actual itinerate traffic mix in a region, which is not the same as the flights attributed to aircraft based in the region. Flights attributed to aircraft based in the region can be determined by totaling the based aircraft by category multiplied by the annual operations per aircraft by category for that region. The traffic mix from aircraft located within the region would be the percentage from each aircraft category. The difference between these numbers is indicative of the traffic mix flows between regions.

SATS00 Worksheet

The purpose of this worksheet is to calculate the numbers of annual itinerate operations by airplane category for each airport in the 3227 airport set. The sheet contains some basic location data in columns A through F. Data contained in addition to the airport number (unique to the SATS Models only) and location identifier are state, FAA region, latitude, and longitude. The total itinerate operations and based aircraft data are read from the ops&AC worksheet. An airport's annual itinerate operations comes from two sources: one from locally based aircraft and the other from aircraft from the outside. Itinerate operations from aircraft based at an airport are calculated by multiplying the based aircraft by category by the regional utilization by category from the UTLIZE worksheet. The difference between airport's total itinerate operations and the number of operations calculated for local aircraft are assumed to be from outside aircraft. The operations by outside aircraft are then assumed to be proportional to the regional traffic mix from the ops_distribution worksheet. Summing the numbers attributed to local and outside aircraft gives the total itinerate operation for an aircraft category. At some airports, generally smaller ones, the numbers of operations calculated for based aircraft using regional utilization numbers exceeds the total number of itinerate operations reported or projected for that airport. In these cases the regional traffic mix, ops_distribution is used to proportionally reduce the operations by aircraft category so that they sum to the correct reported or projected itinerate operations for the airport.

SATS-in Worksheet

This worksheet simply pulls the data from the SATS00 worksheet in the format to input to the Aviation System Analysis Capability (ASAC) SATS Flight Demand Model. The SATS Flight Demand Model generates the O&D traffic flows based on solutions to the gravity model and then generates SATS flights using a Monte Carlo simulation and time of departure probability from ETMS data. Format for input to SATS Model is airport number, airport location identifier, state, FAA region, latitude, longitude, number of single engine itinerate operation, number of multi-engine operations, and to number of jet engine operations. The ASAC and SATS Models are available from the Systems Analysis Branch, Aerospace Systems Concepts and Analysis Competency, NASA Langley Research Center.

Concluding Remarks

A mode choice model that generates on-demand air travel forecasts at a set of GA airports based on changes in economic characteristics, vehicle performance characteristics such as speed and cost, and demographic trends has been integrated with a model to generate itinerate aircraft operations by airplane category at a set of 3227 airports. Numerous intermediate outputs can be generated, such as the number of additional trips diverted from automobiles and schedule air by the improved performance and cost of on-demand air vehicles. The total number of transported passenger miles that are diverted is also available. From these results the number of new aircraft to service the increased demand can be calculated.

Default values for the worksheets are current GA inventories and operations and projections for the future based on current trends and demographics associated with those numbers. These values serve as a baseline to which incremental changes can be made. Any perturbations, such as radically new aircraft or concept of operation, are inserted into the model and incremental changes with respect to the baseline are the benefits metrics. The baseline data is modified for the number of aircraft and operations to account for concepts that disrupt trends by diverting additional traffic from other travel modes, otherwise, the additional transported passenger miles will be produced by the mix of aircraft and operations in the baseline model. The program distributes the operations and aircraft and projects future operations and aircraft basing by a time line regression analysis of demographic data and demographic projections. FAA regional aircraft flight rate and landing distributions by aircraft category are used to project the number of itinerate operations by airplane category at each of the SATS airports. The itinerate operations data by airplane category at each SATS airport feeds additional models (not included in the EXCEL models of this report) that construct O&D pairs and a flight schedule for all GA traffic for a heavy-use day in a particular year.

The Integrated Mode Choice, Small Aircraft Demand, and Airport Operations Model EXCEL workbook is available on CD-Rom as NASA/CR-2004-212998/SUPPLEMENT and can be obtained from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320

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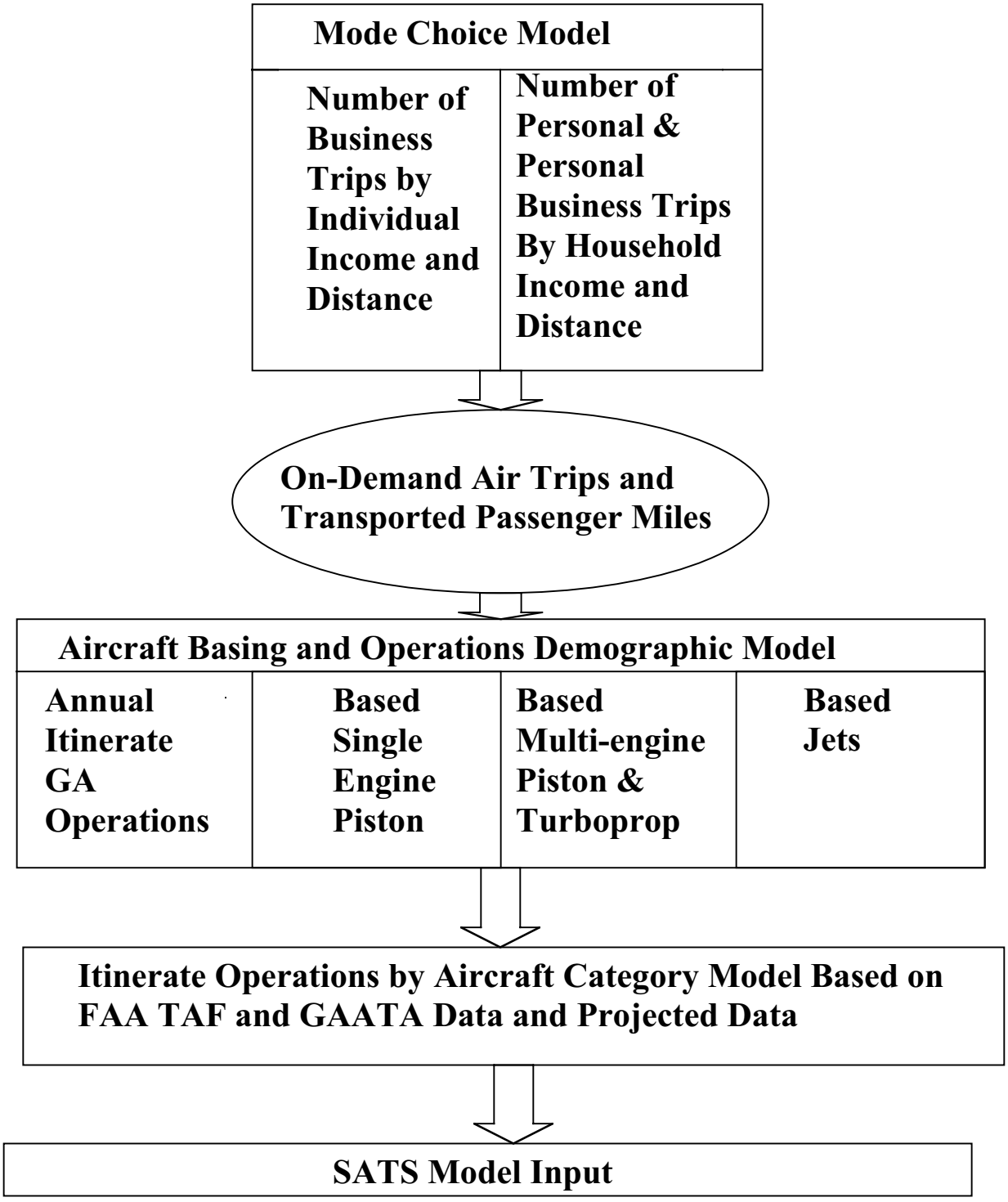

Figure 1 – Model Linkage

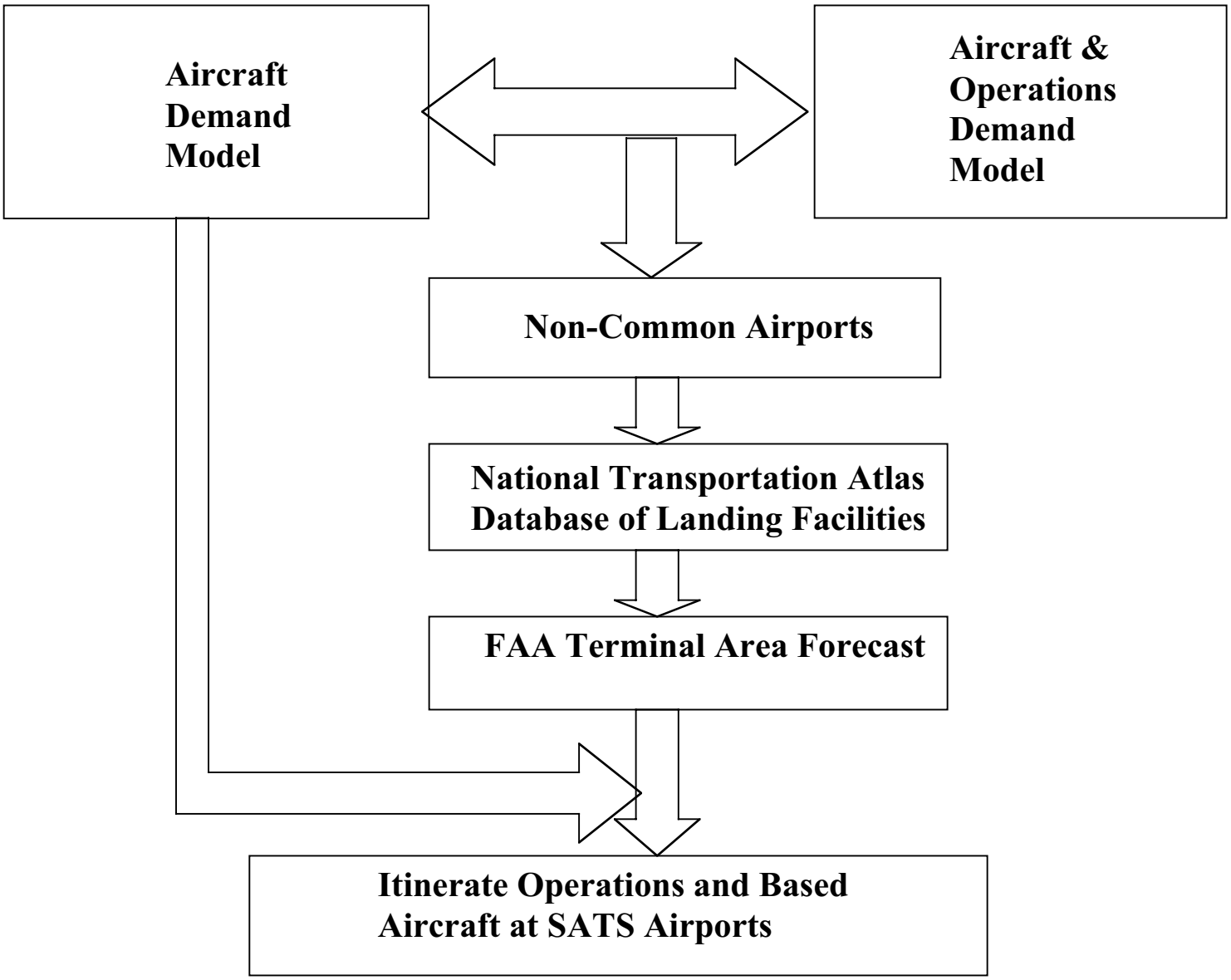

Figure 2 – Airport Reconciliation

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14. ABSTRACT

A mode choice model that generates on-demand air travel forecasts at a set of GA airports based on changes in economic characteristics, vehicle performance characteristics such as speed and cost, and demographic trends has been integrated with a model to generate itinerate aircraft operations by airplane category at a set of 3227 airports. Numerous intermediate outputs can be generated, such as the number of additional trips diverted from automobiles and schedule air by the improved performance and cost of on-demand air vehicles. The total number of transported passenger miles that are diverted is also available. From these results the number of new aircraft to service the increased demand can be calculated. Output from the models discussed is in the format to generate the origin and destination traffic flow between the 3227 airports based on solutions to a gravity model.

15. SUBJECT TERMS

General aviation; Small aircraft; Transportation economic analysis

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